Ambient Groundwater Quality of the Sacramento Valley Basin: An ADEQ 1999 Baseline Study

I. Introduction

The Sacramento Valley Groundwater Basin (SVGB), located in northwestern Arizona (**Figure 1**), is an arid region with striking natural landscapes and a small, but rapidly growing population. The popularity of the area is influenced by its proximity to tourist destinations such as the Colorado River and Laughlin, Nevada, and by an abundance of relatively inexpensive, undeveloped private land. Groundwater is the primary water source for municipal, domestic, industrial, mining, livestock, and irrigation in the basin. Population growth and the associated economic development in the SVGB will likely increase demand on groundwater and, over time, may influence water quality.

These groundwater quality concerns prompted the Arizona Department of Environmental Quality (ADEQ) to conduct a regional groundwater quality study in 1999 to determine groundwater suitability for drinking purposes, appraise current baseline conditions, and examine spatial groundwater quality patterns. This factsheet is a summary of the more extensive hydrology report available from ADEQ (1).

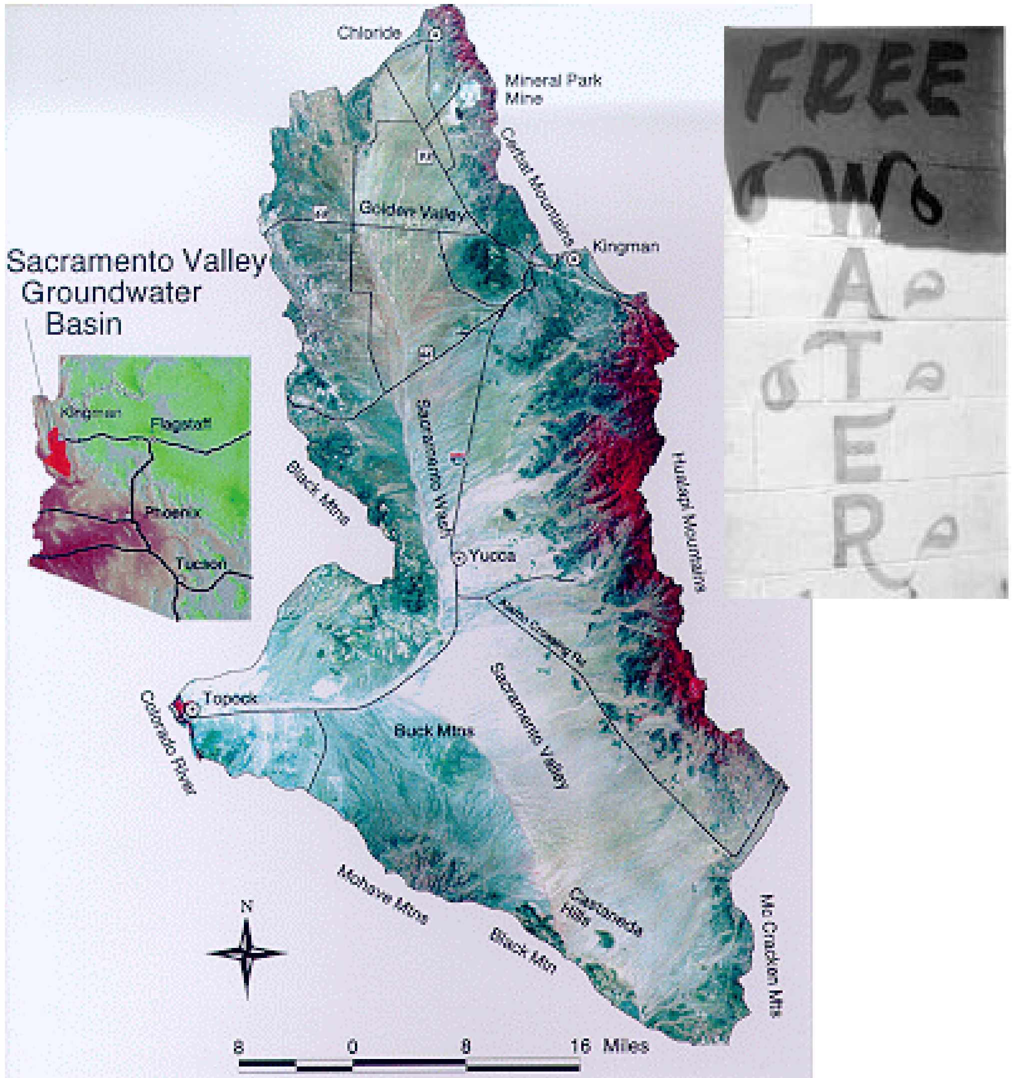

Figure 1. Infrared satellite image (6/1993) of the Sacramento Valley groundwater basin (SVGB). Mountain forests appear crimson, upland areas are dark blue, and valley areas are beige/white. Inset map shows the location of the SVGB within Arizona. Inset photo shows a mural on an abandoned Route 66 gas station located in Yucca that reflects the intense desert conditions found in the basin.

Figure 2. Twin windmills pump to a water tank in the southern Hualapai Mountains.

II. Background

The SVGB encompasses more than 1,500 square miles in Mohave County, Arizona. It is bounded by the Cerbat, Hualapai, and McCracken Mountains to the east, the Castaneda Hills and Mohave Mountains to the south, the Colorado River and the Black Mountains to the west, and an unnamed bajada to the north (**Figure 1**). Basin elevations range from a high of 8,417 feet at Hualapai Peak to a low of 500 feet near the Colorado River and averages 2,500 feet.

Surface topography consists of sloping alluvial fans which extend from the surrounding rugged mountains to the valley floor. Precipitation increases with elevation, averaging 4 inches annually in the valley, 10 inches near the city of Kingman, and more than 20 inches at Hualapai Peak (2). Natural vegetation varies with topography and water availability. Creosote bush, cactus, yucca, and Joshua trees grow in the valleys, whereas juniper, pinyon pine, and scrub oak are found at intermediate elevations, and ponderosa pine forests are abundant above 6,500 feet (2).

> ***"Despite frequent water quality standard exceedances, sampled sites in much of the SVGB met drinking water standards."***

Basin communities include the historic mining town of Chloride, Golden Valley, the city of Kingman, Yucca, and the Colorado River resort community of Topock (**Figure 1**). Most land within the SVGB, particularly rugged upland areas, are managed by the Bureau of Land Management while private and State lands are common in valley areas.

III. Hydrogeology

The alluvium that underlies the valley floor and occurs within mountain canyons is the most important aquifer in the SVGB. These deposits are separated into older, intermediate, and younger alluvium, based on their lithologic and hydrologic properties. The older alluvial aquifer yields and stores the greatest quantity of water in the basin. The intermediate and younger alluvium are less important hydrologically since these units lie predominantly above the water table (2).

The mountains that form the basin consist predominantly of granitic, volcanic, and metamorphic rocks with limited outcrops of sedimentary rocks. While all rock types produce limited amounts of water, especially where extensively fractured, volcanic rocks are the most important source in mountain areas supplying large quantities of water for use in Kingman (2).

For this study, the older, intermediate, and younger alluvium are considered the *alluvial aquifer*. Granitic, volcanic, metamorphic, and sedimentary rock are considered the *hardrock aquifer*.

No perennial streams exist within the SVGB, though a few watercourses flow almost continuously in their upper reaches (2). The main surface water drainage is the ephemeral Sacramento Wash, which originates north of Golden Valley, flows south, then west, and eventually discharges an average of 500 acre-feet per year into the Colorado River near Topock.

Figure 3. A domestic well house and water tank are situated in the shadow of Thimble Mountain, a famous Route 66 landmark west of Kingman.

IV. Methods of Investigation

This study was conducted by the ADEQ Groundwater Monitoring Program which is authorized by the legislative requirement in Arizona Revised Statute §49-225 to monitor the quality of the state's groundwater. To characterize regional groundwater quality, 48 sites (**Figure 4**) were sampled for inorganic constituents (field parameters, general mineral characteristics, major ions, nutrients, and trace elements), volatile organic compounds (VOCs), perchlorate (a man-made inorganic salt), and isotopes of hydrogen, oxygen, and nitrogen. At 40 sites, samples were also collected for radiochemistry analyses.

Of the 48 sampled sites, 40 were random sites and 8 were targeted sites. Sampling protocol followed the ADEQ *Quality Assurance Project Plan*. Interpretation of quality control data indicated that the sampling equipment and laboratory procedures had no significant effects on the analytical results.

V. Water Quality Sampling Results

Groundwater sample results were compared to federal Safe Drinking Water (SDW) quality standards. Primary Maximum Contaminant Levels (MCLs) are enforceable, health-based, water quality standards that public water systems must meet when supplying water to customers (3). Primary MCLs are based on a lifetime consumption of two liters of water per day (3). Of the 48 sites sampled, 22 had constituents that exceeded a Primary MCL (**Figure 4**). Constituents with Primary MCL exceedances included gross alpha (18 sites), nitrate (6 sites), fluoride (4 sites), radium-226+228 (4 sites), and antimony (2 sites).

Secondary MCLs are unenforceable, aesthetics-based, water quality guidelines for public water systems (3). Water with Secondary MCL exceedances may be unpleasant to drink and/or create unwanted cosmetic or laundry effects but is not considered to be a health concern (3). Of the 48 sites sampled, 28 exceeded Secondary MCLs including total dissolved solids or TDS (24 sites), fluoride (16 sites), sulfate (7 sites),

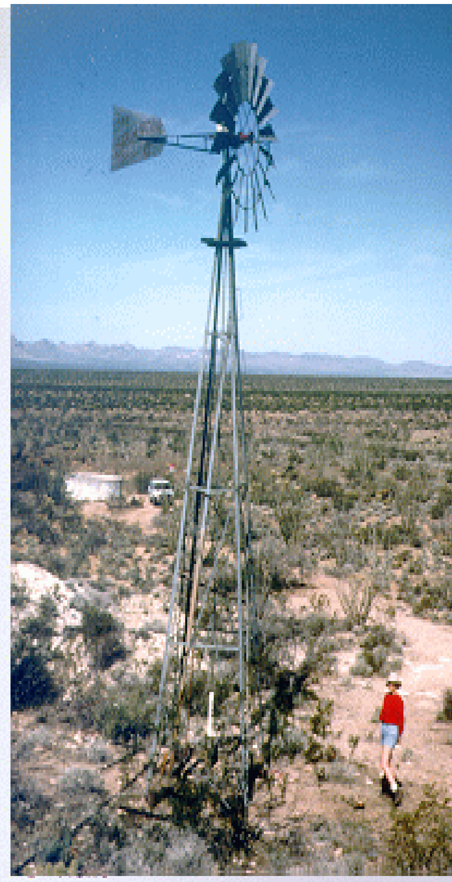

Figure 6. ADEQ staff sample a windmill on the western flank of the Hualapai Mountains. The windmill pumps water for stock use; the Black Mountains are in the background.

Granitic Rock

Figure 4. Water quality exceedances most commonly occur near the town of Chloride, in granitic areas of the Hualapai Mountains, and in downgradient areas of the basin near Topock.

chloride (7 sites), manganese (3 sites), and iron (2 sites) (**Figure 4**).

VOCs were not detected at any sample site. Perchlorate, an inorganic salt used in the manufacture of solid fuel propellants and explosives, was detected in the northwest part of the basin at four sites. All perchlorate detections were at concentrations below the Arizona provisional Drinking Water Health-Based Guidance Level of 31micrograms per liter (Fg/l).

> ***"Sample sites exceeding water quality standards generally occurred in three areas: (1) near the town of Chloride, (2) in the central and southern Hualapai Mountains, and (3) near the town of Topock."***

VI. Groundwater Composition

In general, groundwater in the SVGB is *slightly alkaline* (pH > 7 standard units), *fresh* (TDS < 1000 milligrams per liter or mg/l), and ranges from *moderately hard* to *very hard*. Groundwater chemistry is frequently of a *calcium-bicarbonate* type, however, *calcium-sulfate* and *sodium-bicarbonate* sites were also identified. The only *sodium-sulfate* samples were collected at the two most downgradient sites near Topock. Nitrate (as nitrogen) concentrations were greater than 3 milligrams per liter (mg/l) at 42 percent of sites, which may indicate impacts from human activities. Most trace elements such as aluminum, antimony, barium, beryllium, cadmium, iron, lead, manganese, mercury, silver, and thallium were rarely detected. Arsenic, boron, chromium, copper, fluoride, selenium, and zinc were the only trace elements detected at more than 10 percent of the sites.

VII. Groundwater Spatial Patterns

Bicarbonate, calcium, gross beta, hardness, magnesium, specific conductivity (SC), total alkalinity, TDS, and total Kjeldahl nitrogen (TKN) were higher in the *hardrock aquifer* than in the *alluvial aquifer*. The opposite pattern was apparent for pH and temperature (Kruskal-Wallis test, p# 0.05). This *hardrock-alluvial aquifer* constituent pattern has been noted in other Arizona groundwater basins (1).

To further examine groundwater quality patterns within the basin, geologic categories (granitic, volcanic, metamorphic, sedimentary, and alluvial fill) were compared. Generally, groundwater associated with granitic rock had significantly greater constituent concentrations than groundwater associated with alluvial fill, metamorphic rock, and volcanic rock (Kruskal-Wallis and Tukey test, p# 0.05). Thus, many of the *hardrock-alluvial aquifer* patterns are related to differences between groundwater associated with granite and other rock classifications.

Boron, fluoride, gross alpha, pH, sodium, sulfate, temperature, and zinc were higher in the southern, downgradient areas than the northern upgradient areas of the basin (Kruskal-Wallis test, p# 0.05). The opposite trend occurred with magnesium.

Similar patterns were found by assessing the strength of association among concentrations of various constituents. Depending on the dominant cation, there were two general patterns. With calcium, correlations occurred among magnesium, bicarbonate, sulfate, hardness (all positive), and pH (negative). With sodium, positive correlations occurred with boron (**Figure 5**) as well as with chloride, sulfate, and fluoride (Pearson Correlation Coefficient test, p# 0.05).

These test findings support the observed flowpath evolution in the SVGB. Along the groundwater flowpath, that parallels the course of Sacramento Wash (2), calcium, magnesium, bicarbonate, and hardness concentrations generally decreased downgradient. In contrast, sodium, chloride, fluoride, and boron concentrations initially decreased, and then increased dramatically in downgradient areas. These flowpath changes appear to indicate that the SVGB is largely a *chemically closed basin*, or one in which the aqueous chemistry is determined mainly by the reactions of recharge waters with the various *in situ* minerals and gases as the groundwater moves downgradient (4).

VIII. Groundwater Depth Patterns

Bicarbonate, calcium, gross alpha, gross beta, hardness, SC, total alkalinity, and TDS decreased with increasing groundwater depth below land surface

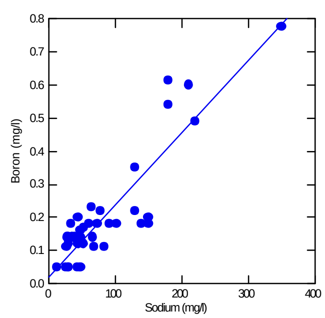

Figure 5. Boron concentrations generally increase with increasing sodium concentrations (Pearson Correlation Coefficient test, p#0.01)

(bls). In contrast, pH and temperature increased with increasing groundwater depth bls (regression analysis, p# 0.05). Many of these constituents show a similar pattern to hardness (**Figure 7**) which attains a *critical level* at approximately 150 feet bls. Hardness concentrations remain generally constant at groundwater depths greater than the *critical level* and are highly variable at more shallow depths. Approximate *critical levels* for other constituents significantly correlated with groundwater depth ranged from 50 feet bls for gross alpha to 200 feet bls for TDS.

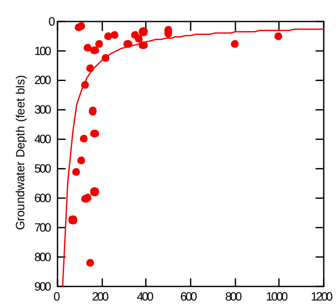

Figure 7. Hardness generally decreases with increasing groundwater depth bls (regression analysis, p # 0.01).

IX. Groundwater Changes

A time-trend analysis was conducted based on data collected from 14 wells by the U.S. Geological Survey in 1979, the Arizona Department of Water Resources in 1990, and ADEQ in 1999. Sixteen (16) constituents were compared over three time periods. Temperature and pH were the only parameters that varied significantly between 1990 and 1999 (Wilcoxon ranked-sum test, p# 0.05).

X. Groundwater Conclusions

Although groundwater in much of the SVGB met water quality standards, approximately one-half of sample sites in the basin did not meet water quality standards. Thus, ADEQ suggests that well owners periodically have their groundwater analyzed by certified laboratories. The majority of sample sites that exceeded water quality standards occurred in three areas:

- Near the town of Chloride
- In the central and southern Hualapai Mountains
- Near the town of Topock

Although only limited time-trend analyses were conducted for this study, constituents in most areas of the basin appear to be controlled by natural geochemical reactions and would probably not vary significantly in the short term. Sites exceeding water quality standards in the Hualapai Mountains and near Topock appear to be the result of natural conditions. Previous studies have noted that groundwater found in and near the mountains is generally more mineralized than groundwater in the center of the valley (2). Elevated fluoride, TDS, and chloride levels near Topock may be due to dissolution reactions that increase constituent concentrations as groundwater migrates downgradient within the basin (4).

In contrast, some water quality exceedances in the Chloride area appear to be influenced by anthropomorphic activities. Elevated radiochemistry concentrations appear to be related to granitic rock that occurs in much of the Hualapai and Cerbat Mountains, but are likely exacerbated by nearby, mostly inactive mines. Nitrate levels, which sometimes exceed water quality standards at sites in Chloride, appear to be related to the high-density of older septic systems used for domestic and commercial wastewater treatment. These systems are often situated in soils that are classified as marginally suitable for septic use. Other indicators of septic system impacts, TDS and chloride, are also frequently elevated over Secondary MCLs at sites in the Chloride area.

Groundwater Dating Method

Stable isotopes of oxygen (oxygen-18) and hydrogen (deuterium) were analyzed to examine the origin and age of groundwater in the basin. Isotopic data was compared to the Global Meteoric Water Line (GMWL), the standard reference water based upon world-wide precipitation data which has not been exposed to evaporation (4). The SVGB data lie below and to the right of the GWML, which is characteristic of waters exposed to evaporation (4). This pattern suggests that SVGB groundwater is probably derived from local recharge, the majority of which occurred in the distant past.

Nitrogen isotopes (nitrogen-15) were also collected to assist in determining sources of nitrate in groundwater. However, interpretation of the results suggest that pinpointing the nitrate source was not possible using this method without techniques to determine basin-specific groundwater signatures of various nitrate sources found in the area.

Figure 8. Alkali Spring emerges in the arid Black Mountains and ponds in this depression, providing both valuable riparian habitat and a perennial water source for livestock and wildlife.

---Douglas Towne and Maureen Freark
Maps by Larry W. Stephenson
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References Cited

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